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ENGINEERING DIVISION

Visit to Research Laboratories, Telefunken A. G., Hannover

9th. June, 1964

Visit Report No. A-084

1964/39

THE BRITISH BROADCASTING CORPORATION

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1. INTRODUCTION

The visit was made to the Research Laboratories of Telefunken A.G., Hannover in order to study the latest PAL-system developments made by Herr Bruch and his colleagues. To date Herr Bruch has not published much information concerning transcoding and most of the day spent at the laboratory consisted of discussing several of his new proposals and seeing demonstrations of one or two that have been instrumented. Herr Jaeschke of the Fernmeldetechnisches Zentralamt, Darmstadt, was present during the discussions and demonstrations.

2. GENERAL

The fact that the PAL signal is more resistant than the NTSC signal to certain forms of distortion leads to the possibility of transcoding between the two systems, so that a PAL signal may be used at those points in a transmission chain where distortion would be troublesome in terms of an NTSC signal.

An approach to the problem of transcoding from PAL to NTSC has been published.[1] In this arrangement the PAL chrominance signal is first separated into I and Q chrominance components by means of a one-line delay together with sum and difference circuits, as in the PAL delay-line decoder. The output of the "summing" circuit consists of Q chrominance signals, whilst the output of the difference circuit consists of I chrominance signals alternating in phase line by line; these phase alternations are then removed by an electronic switch. As a result, I and Q chrominance signals, of somewhat reduced vertical resolution, are available for recombining with the luminance signal, from which input chrominance components have been removed, to form an NTSC composite signal. It is apparent that this form of transcoder permits no change of subcarrier frequency and, as far as is known, demonstrations of this arrangement in the past have always taken place using the PAL subcarrier to line-frequency relationship, thus producing a non-standard NTSC signal.

The new transcoding proposals are more realistic in terms of the practical requirements and some of them rely on recent developments in subcarrier reference-oscillator control techniques. For the purpose of clarity this report first reviews these developments and then outlines the transcoding proposals.

Several of the ideas and developments described by Herr Bruch, and outlined in this report, have not yet been covered by patents and an undertaking was given that, in such cases, the information would be treated as confidential. Herr Bruch is at the moment preparing a paper which will be published in the Telefunken Zeitung; however, he has undertaken to provide, in the meantime, an advance copy of his paper as soon as it has been put into a suitable form.

3. SUBCARRIER REFERENCE OSCILLATOR CONTROL

3.1 "New-PAL"

Details have been published recently[2,3] of means for controlling the subcarrier reference-oscillator in a decoder during the active portion of each line; this control is additional to that provided by the normal burst in the line-blanking interval. Herr Bruch refers to this technique as "New-PAL". Two embodiments of this proposal were described. In the first, the separate I and Q chrominance signals, obtained from a one-line delay with sum and difference circuits, are subjected to full-wave rectification and then suitably combined to produce a wave whose frequency is twice that of subcarrier. It can be shown that the phase of this double-frequency wave is constant and independent of chrominance phase angle. The second consists of multiplying the input PAL chrominance signal by the corresponding chrominance signal that occurred during the previous line and again involves a one-line delay. This process results, as before, in a wave whose frequency is twice that of subcarrier and whose phase is independent of that of the chrominance signal. In each embodiment the double-frequency wave may then be used to control the phase of an l.c. subcarrier reference-oscillator in the decoder throughout the active line, provided that a sufficient amplitude of chrominance signal is present. It will be appreciated that the subcarrier control during the line is absent in monochrome areas and that the phase of the double-frequency wave is in error at a horizontal boundary between areas of different colour.

The New-PAL technique was illustrated by Herr Bruch in a series of demonstrations. First, it was shown that a variation in the phase of the burst signal (i.e. a chrominance phase error independent of luminance-signal magnitude) of ± 90° had negligible effect upon the picture obtained from the New-PAL decoder. The same degree of burst phase shift was demonstrated using NTSC and then using PAL with a conventional delay-line PAL decoder (i.e. incorporating a crystal-controlled subcarrier reference-oscillator); in the case of NTSC the colour errors were very serious and, in the case of the PAL with the conventional delay-line decoder, the desaturation of coloured areas was very obvious. Secondly, the effects of differential-phase distortion were demonstrated using a slide showing bright yellow flowers against a mainly monochrome background; it was stated that the degree of differential phase distortion was of the order of 25° for a bright yellow. The effect of such distortion using NTSC was very obvious. Using PAL with a conventional delay-line decoder resulted in a significant desaturation of the yellow areas. No effects due to differential-phase distortion were seen using PAL with the New-PAL decoder. Thirdly, the effects of head-to-tape velocity variations in a magnetic recorder were simulated by introducing a chrominance phase error that was zero at the beginning of each line but progressively increased to at least 90° at the end of each line. Again the effects on the picture, when using NTSC, were very serious. Using PAL and a conventional delay-line decoder resulted in very obvious desaturation of those coloured areas on the right-hand side of the picture. Using PAL and the New-PAL decoding technique, no effects due to the progressive phase shift were visible.

As a result of a request Herr Bruch readily agreed to demonstrate the error introduced, with the New-PAL decoding technique, at horizontal boundaries between areas of different colour. This demonstration employed a colour-bar signal in which the stripes of different colour were arranged in the field direction instead of in the line direction. On close inspection it was possible to see the narrow regions of desaturation and colour error at some of the boundaries.

Various pictures were used during the whole series of New-PAL demonstrations, including several producing little chrominance information. No effects that could be attributed to loss of reference-oscillator synchronism were detected. Herr Bruch was questioned as to whether this form of subcarrier reference-oscillator control was more sensitive to random noise than the more conventional techniques. He stated that the New-PAL decoder was no more sensitive to random fluctuation noise than a conventional NTSC arrangement, except for signal-to-noise ratios well below the level at which the picture becomes unusable. With a very low signal-to-noise ratio the control effected by the burst fails to keep the phase of the l.c. oscillator, at the beginning of each line, within ± 90° of the correct value; as a result the oscillator may lock to the double-frequency wave with 180° phase error.

Herr Bruch described some tests in which a PAL signal was recorded on magnetic tape using a TR22 R.C.A. recorder; the replayed signal was then fed to a New-PAL decoder. Neither Amtec nor Colortec (or R.C.A. equivalent) was used. He projected some photographs showing the results obtained using colour pictures and colour bars. The pictures showed negligible hue errors; they were, however, marred by horizontal white lines that corresponded to those instants at which head switching occurred (i.e. the boundaries between head bands). It was pointed out that, immediately after such a change from one head to another, the chrominance signal could have a phase error of greater than 180°, thus causing an incorrect locking of the subcarrier reference-oscillator in the decoder. However, this locking is corrected by the first burst signal to be received after the head-switching operation. Herr Bruch pointed out that the New-PAL subcarrier reference-oscillator control technique could possibly be applied to the control of Colortec, thus giving some additional correction during the active portion of each line.

In reply to a question, he stated that no tests had yet been carried out to determine the sensitivity of the technique either to CW interference or to strong luminance-signal components near subcarrier frequency.

3.2 "New-New-PAL"

It will be appreciated that the New-PAL proposal is concerned only with decoding technique and is, therefore, not a proposal to modify the PAL system. However, Herr Bruch has now suggested that, by means of a relatively simple modification to the PAL chrominance signal, further improvements can be made in decoding technique. He refers to the modified signal, together with the corresponding decoding techniques, as "New-New-PAL". The modified signal contains a burst whose phase, on successive lines, alternates symmetrically about the -Q chrominance axis. This is illustrated in Fig. 1. In a preferred arrangement the burst phase, with reference to the phase of -Q, during one line is -45° and on the succeeding line is +45°. When this signal is fed to a one-line delay with sum and difference circuits the output of the sum circuit consists of the Q chrominance signal together with a burst component whose amplitude and phase is constant, (i.e. the -Q component of each burst). However, the output from the difference circuit consists of an I chrominance signal together with a burst component that alternates in phase. If a crystal oscillator is used in the decoder the alternating I component of burst may be used to synchronize the electronic switch. However, if the subcarrier reference-oscillator control technique of New-PAL is adopted two l.c. subcarrier reference-oscillators may be used in the decoder. The first oscillator employs the -Q component of burst and is controlled during the line by the double-frequency wave produced from the I and Q chrominance signals; the output of this first oscillator is then used to demodulate the Q chrominance signal. However, the second oscillator employs the alternating I component of burst at the beginning of each line but is again controlled during the line by the double-frequency wave. The fact that the control derived from the I component of burst alternates line by line results in a subcarrier reference-oscillator output that also alternates in phase line by line. This wave may then be used to demodulate the I chrominance signal directly, thus dispensing with the need for an electronic switch in the decoder.

Herr Bruch stated that, as far as sensitivity to distortions is concerned, the New-New-PAL decoding technique is identical with New-PAL. He pointed out that it would be possible to modify the PAL signal to the New-New-PAL form without rendering earlier forms of PAL decoder useless, provided that the "identification" signal, transmitted during the field blanking and used to ensure correct operation of the decoder electronic switch, were retained. The crystal oscillators of simple PAL and conventional delay-line PAL decoders would lock with a phase that is the average of the two burst phases radiated on successive lines; this average phase lies along the -Q chrominance axis. Thus if the signal were changed to conform with New-New-PAL, the reference-subcarrier phase in simple PAL and conventional delay-line PAL decoders would need to be phase shifted by 33°; this is, in effect, a rotation of the hue control. The fact that the effective component of the burst used by the simple PAL and conventional delay-line PAL decoders, under these conditions, would be perhaps 3 dB lower in amplitude could be compensated by increasing the amplitude of the alternating burst by 3 dB. A New-PAL decoder was shown to operate quite satisfactorily using the New-New-PAL signal. However, the line-by-line variation of say ± 45° in burst phase may be expected to absorb some of the tolerance of a New-PAL decoder to phase errors.

4. TRANSCODING

The transcoding technique mentioned in section 2 consisted, in essence, of splitting the input composite signal into chrominance and luminance signals, transcoding the chrominance signal to conform to the required system and then forming the output by adding a somewhat degraded luminance signal obtained from the input. Herr Bruch's new approach to transcoding relies upon splitting the input signal spectrum into two frequency bands. Ideally, the low-frequency band consists of luminance components only and is passed direct to the output of the transcoder. The high-frequency band consists of the chrominance signal plus all the high-frequency luminance components. This high-frequency band is transcoded as an integral whole and is then added to the low-frequency band to form the output.

The success of this technique depends to a considerable extent upon the accuracy with which the input signal spectrum can be split into two bands without introducing amplitude and group-delay errors at the "crossover" frequency. Up to the present, Herr Bruch has used a low-pass filter, with some group-delay correction, for extracting the low-frequency components and a band-pass circuit for extracting the high-frequency components. He has encountered some problems with this arrangement and, at the moment, is considering the use of minimum-phase networks only. In the opinion of the authors, this is probably not the best method of performing the splitting process.

4.1 The modifier

The transcoding of the high-frequency components is effected by a device Herr Bruch has named the "modifier". This modifier consists of a balanced modulator in which the input chrominance and high-frequency luminance components are heterodyned by a wave at twice the subcarrier frequency. Of the two sets of modulation products produced, those of lower frequency are selected. The modifier can be shown to produce an output that is the complex conjugate of its input; thus if the modifier input has a chrominance phase error, the modifier output has an equal but opposite phase error. The action of the modifier and its use in the transcoder are shown in Fig. 2. It will be seen that if the input to the transcoder consists of a PAL chrominance signal in which the first line has a +I component, the second line a -I component and the third line again a +I component, the output of the modifier will consist, during the first line, of chrominance with a -I component, during the second line with a +I component and during the third line with a -I component; the Q component is unmodified. Thus, by suitable operation, the electronic switch can successively select, line by line, chrominance and high-frequency luminance components from either the input to the modifier or from its output. In this way, an input PAL chrominance signal is converted into a form of NTSC chrominance signal in which any phase error (associated with the PAL signal) is converted into an alternating phase error in the output NTSC signal. Correspondingly, an NTSC chrominance signal can be converted into a PAL chrominance signal at the output. When transcoding from PAL to NTSC, the alternating phase error in the output NTSC chrominance signal may be removed by passing the signal derived from the electronic switch to a one-line delay and adding together the signals appearing at the input and output of this delay. This process causes the phase error to be cancelled at the cost of a reduction in chrominance amplitude (and hence saturation) related to the cosine of the phase error. In addition, vertical chrominance resolution is somewhat reduced.

It will be appreciated that the action of the modifier is to produce a "mirror-image", about subcarrier frequency, of the high-frequency components of the input signal. If the input signal is of the "equi-band" form, in which the chrominance bandwidths of the I and Q (or R - Y and B - Y) signals are nominally equal and symmetrically disposed about subcarrier frequency, and if the splitting of the input-signal spectrum is carried out efficiently, the frequency band occupied by the transcoder output is approximately equal to the bandwidth of the input. This is illustrated in Fig. 3 where (a) represents the input spectrum, after splitting and (b) represents the output spectrum during a line in which the output high-frequency band is obtained from the modifier.

When, however, the input signal to the transcoder has the normal form of NTSC or PAL spectrum (i.e. narrow double-sideband Q chrominance and wide asymmetric-sideband I chrominance), and if the high-frequency band is to contain all the chrominance information, two consequences would appear to follow. First, the crossover frequency of the two bands must be lowered and secondly, the bandwidth occupied by the output of the transcoder is appreciably greater than that of the input. These points are illustrated in Fig. 4.

Herr Bruch did not comment on the problems posed if the crossover frequency were to be located so that the single-sideband component of the I chrominance signal is included in the low-frequency band; such an arrangement might possibly prove workable where two transcoding operations are involved, the system of the final output being identical to that of the input. He tended to the view that little, if anything, would be lost if NTSC and PAL signals employed only double-sideband chrominance signals with bandwidths equal to that at present allocated to Q chrominance. He did not describe, in any detail, the action of the modifier upon the high-frequency luminance components, but it will be appreciated that these components are treated in an exactly similar manner to the chrominance components.

Herr Bruch then demonstrated transcoding from equi-band NTSC (with the NTSC subcarrier-to-line frequency relationship) to PAL. The output consisted, therefore, of a PAL signal with the NTSC subcarrier-to-line frequency relationship. The output was viewed in both colour and monochrome. The colour picture was marred by vertical columns of subcarrier dots on colour transitions and by a stationary and very visible cross-colour pattern in areas of luminance detail. The black-and-white picture showed a very visible subcarrier pattern including vertical columns of dots in areas of saturated colour. Using a black-and-white test-card slide the resolution wedges of the test-card were marred by appreciable beats between the subcarrier pattern and the luminance detail. The transcoder used was based upon the principles outlined above and incorporated a crystal oscillator for generating the twice subcarrier-frequency wave. Herr Bruch then demonstrated transcoding from equi-band NTSC (with the NTSC subcarrier-to-line frequency relationship) to PAL (with the NTSC subcarrier-to-line frequency relationship) and back to NTSC. Colour and monochrome pictures obtained at the final NTSC output were viewed and could be compared with corresponding pictures obtained from the NTSC input to the transcoding chain. In this case, the pictures obtained by this double transcoding were very satisfactory; the colour picture showed the normal subcarrier pattern on transitions between coloured areas and the cross-colour was of the normal NTSC form. The black-and-white picture showed the normal subcarrier pattern in areas of colour and showed a satisfactory reproduction of the resolution wedges of the monochrome test-card. However, there were some unwanted effects visible in the high-frequency portion of the resolution wedges; some dot pattern could be seen and the picture showed phase errors in that portion of the wedge that corresponded to the cross-over frequency at which the two components of the spectrum were separated.

4.2 Further developments

Herr Bruch then outlined a proposed extension of his transcoding technique by means of which a PAL signal, with fixed-phase or differential-phase errors, may be corrected before transcoding. In this arrangement the PAL signal is heterodyned, in a balanced modulator, by a twice-subcarrier frequency wave produced by beating together the output of a crystal oscillator, locked to the input-signal burst, and the output of an l.c. oscillator controlled according to the New-PAL technique (see section 3.1). The corrected, but non-standard, PAL signal obtained from the balanced modulator may now be fed to the modifier and electronic switch arrangement shown in Fig. 2(c). In this way the NTSC output can be arranged to be free of phase errors and the requirement for a delay line to average the phase errors is removed; thus no loss of vertical chrominance resolution occurs.

Herr Bruch's most recent proposal concerned with transcoding employs heterodyne techniques similar to those found in frequency synthesizers. The prime object of this proposal is to perform transcoding in which the subcarrier-to-line frequency relationship is changed; this, of course, means that the actual subcarrier frequency is changed. In essence the proposal consists of a double-heterodyne system in which the input chrominance signal and high-frequency luminance components are heterodyned to a relatively high frequency, in order to perform adequate filtering operations and are then heterodyned again to the frequency band required. In addition an electronic switch permits the phase alternations required to transcode,on the one hand, from NTSC to PAL or, on the other hand, from PAL to NTSC, to be carried out. Two applications of this proposal were mentioned by Herr Bruch. The first is concerned with changing the frequency of the chrominance components from, say, those corresponding to a U.S. 525-line, 60 field colour system, to those corresponding to a European 525-line, 60 field system. Secondly, this technique could possibly be used to correct timing errors in the colour signal obtained from a magnetic recorder.

5. MISCELLANEOUS

During the visit Herr Bruch demonstrated four R.C.A. colour receivers of recent design which he has modified, at the request of the Italian engineers, so as to be switchable rapidly between NTSC, simple PAL and delay-line PAL. The modification consists of a small transistorized unit which is fitted to the under-side of the cabinet. Herr Bruch stated that in order to get satisfactory performance from these receivers he has had to take considerable care in realigning them. The receivers were demonstrated using signals that had originated at Cologne and been transmitted over the D.B.P. microwave system via Frankfurt and Hamburg to both U.H.F. and V.H.F. transmitters in the Hannover area.

Both NTSC and PAL signals were radiated, the systems changing every five minutes or so. Little difference was seen between the pictures obtained using the two systems except that changing from a U.H.F. to V.H.F. station on NTSC or simple PAL required a slight adjustment of the hue control.

Herr Bruch has recently acquired a Motorola 19" colour receiver incorporating a rectangular tube; however, this was not seen in operation. Finally Herr Bruch indicated that he is investigating the characteristics of some 14" and 17" rectangular colour tubes of Japanese manufacture.

6. CONCLUSIONS

6.1 New-PAL

This is a technique applied in a delay-line decoder. It removes saturation errors in the output which result from fixed-phase or differential-phase errors. As demonstrated it was very effective and in the opinion of the authors should be studied in view of its application to transcoding. Investigation of its noise performance would, for example, be of interest. Although the New-PAL reference-oscillator control technique replaces the crystal oscillator by an l.c. oscillator of relatively simple design, it is unlikely that it could result in any appreciable saving in the cost of a domestic receiver decoder.

6.2 New-New-PAL

Although, strictly speaking, this proposal is a change of system (as a result of the change in the specification of the radiated signal) it is aimed at a further improvement in decoder operation. The need for identification signals is removed and this can simplify the decoder design. However, the New-New-PAL signal can contain the identification signals so as to be usable by simple-PAL, conventional delay-line PAL and New-PAL decoders. In the authors' opinion the New-New-PAL development is not of prime interest at present.

6.3 Transcoding

Herr Bruch has made a more realistic approach to this problem. His demonstrations show that transcoding from NTSC to PAL followed by transcoding from PAL to NTSC gives a satisfactory result when the interconnection between the two transcoders (carrying the PAL signal) is distortionless. It is confidently expected that the tolerances of this link in terms of differential-phase and fixed-phase errors would be much wider than those demanded by NTSC. However, nothing is known of the tolerances required in terms of differential-gain errors, and amplitude and group-delay errors as functions of frequency.

6.4 Recommendations

Herr Bruch has undertaken to make every effort to loan equipment to the BBC in order that further studies may be carried out. First, a New-PAL decoder unit should be available very soon and it is recommended that its characteristics be measured in detail. Secondly, two nominally identical transcoders should also be available soon. Their intrinsic characteristics should be measured and, by arranging them in a suitable sequence, the tolerances of the link connecting them should then be determined.

7. ACKNOWLEDGEMENTS

The authors wish to express their appreciation for the efforts made by Herr Bruch and his colleagues in describing and demonstrating the developments reviewed in this report.

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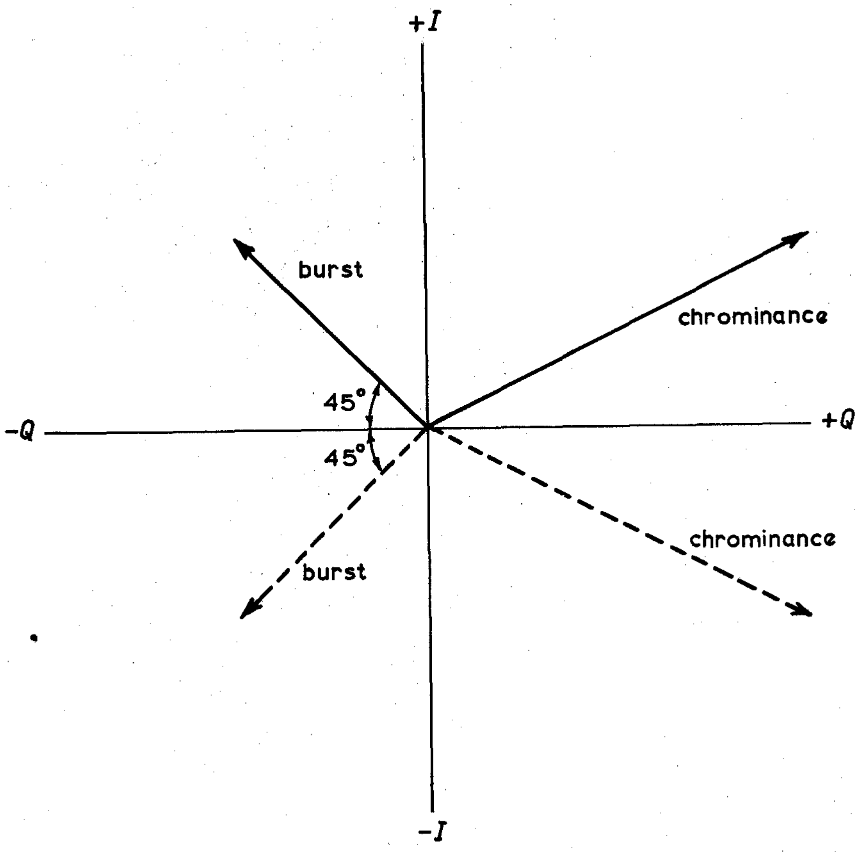
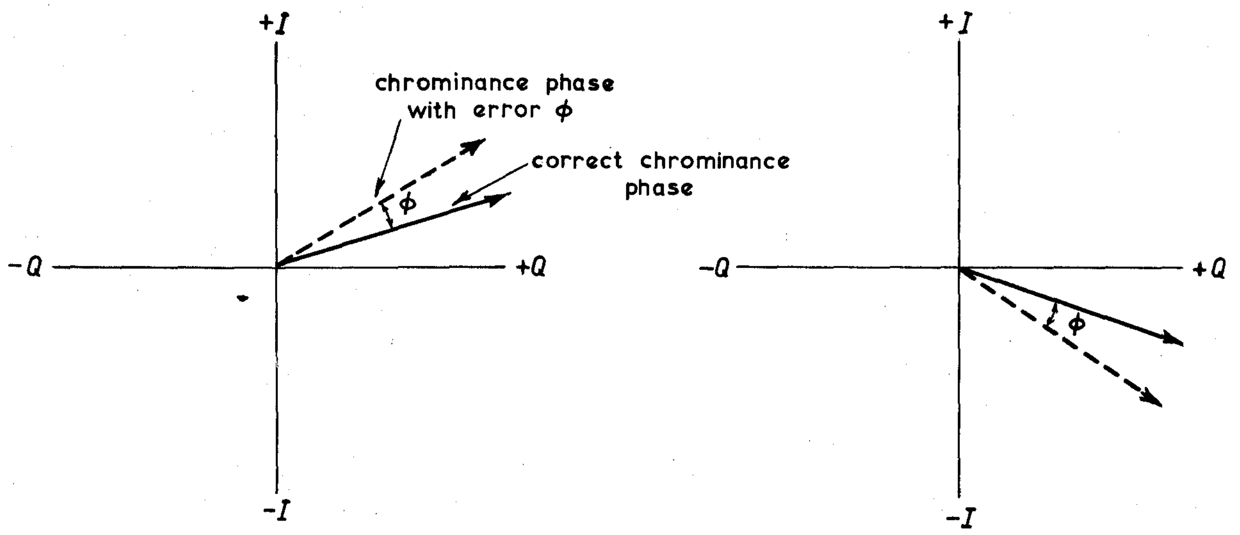


Fig. 1 Vector diagram of chrominance and burst in "New–New" PAL

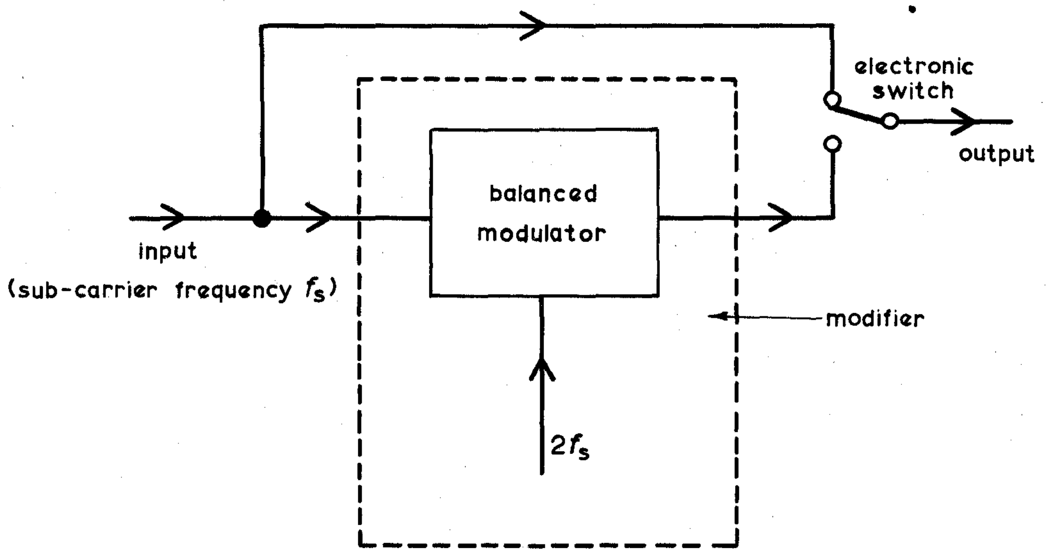
——— Signals transmitted during one line

------ Signals transmitted during succeeding line


+I
chrominance phase with error ϕ
correct chrominance phase
ϕ
−Q
+Q
−I
+I
−Q
+Q
ϕ
−I

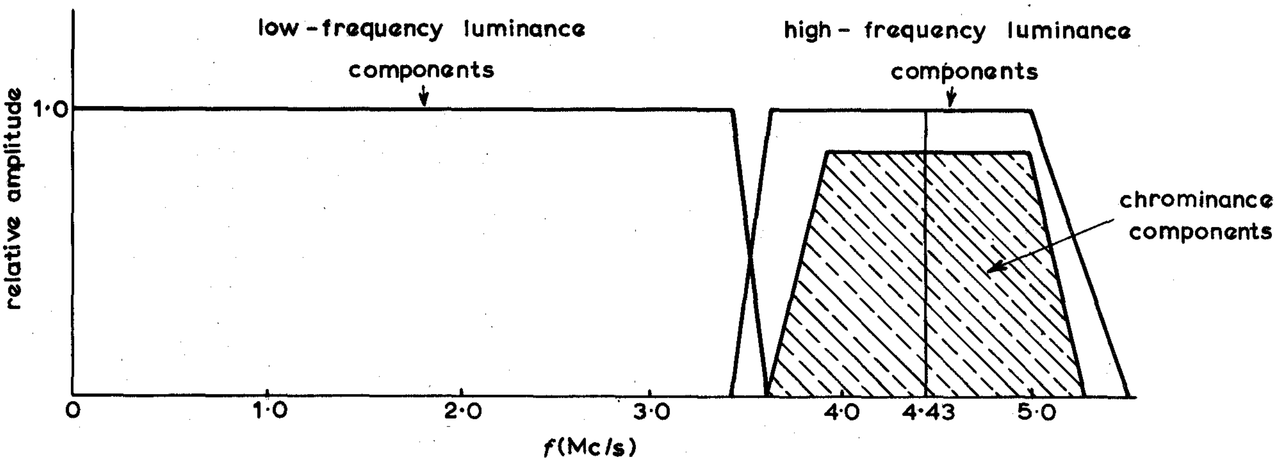
(a) Chrominance vector diagram of input showing a chrominance phase error ϕ

(b) Chrominance vector diagram at output of modifier, for input shown in (a)

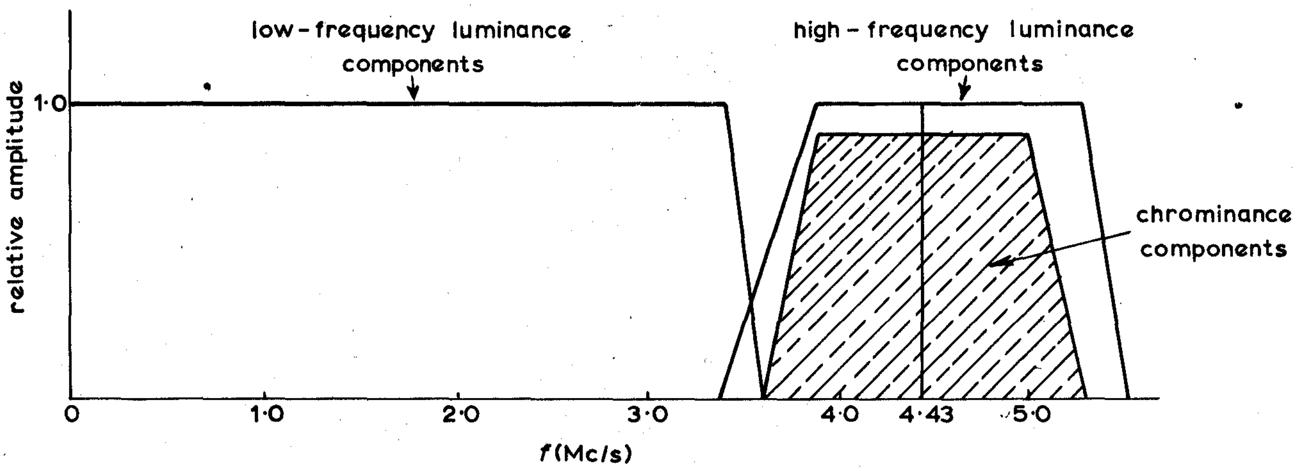


(c) A transcoder consisting of a modifier and an electronic switch

Fig. 2 Transcoding by means of a modifier

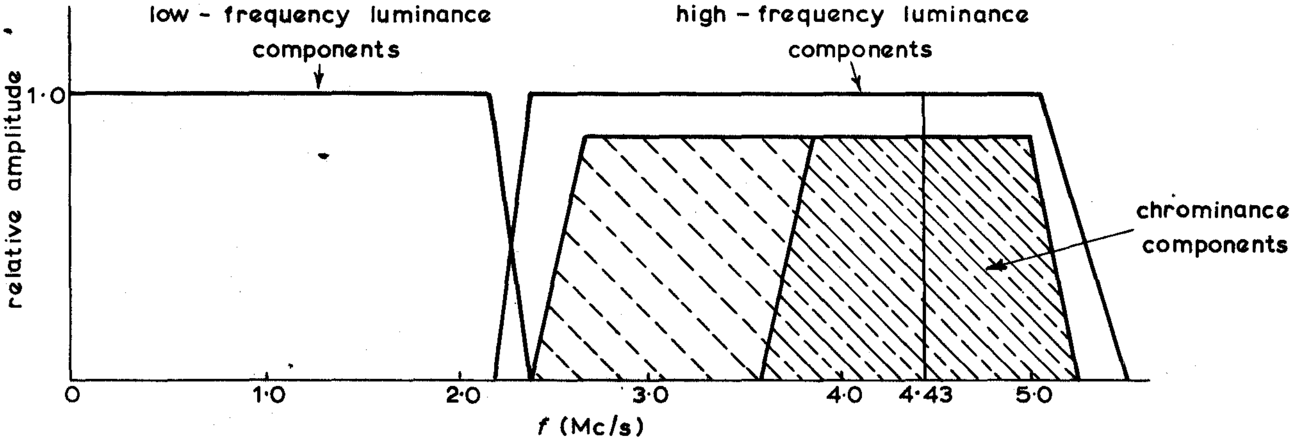


(a) Input signal spectrum after splitting into low and high-frequency bands.

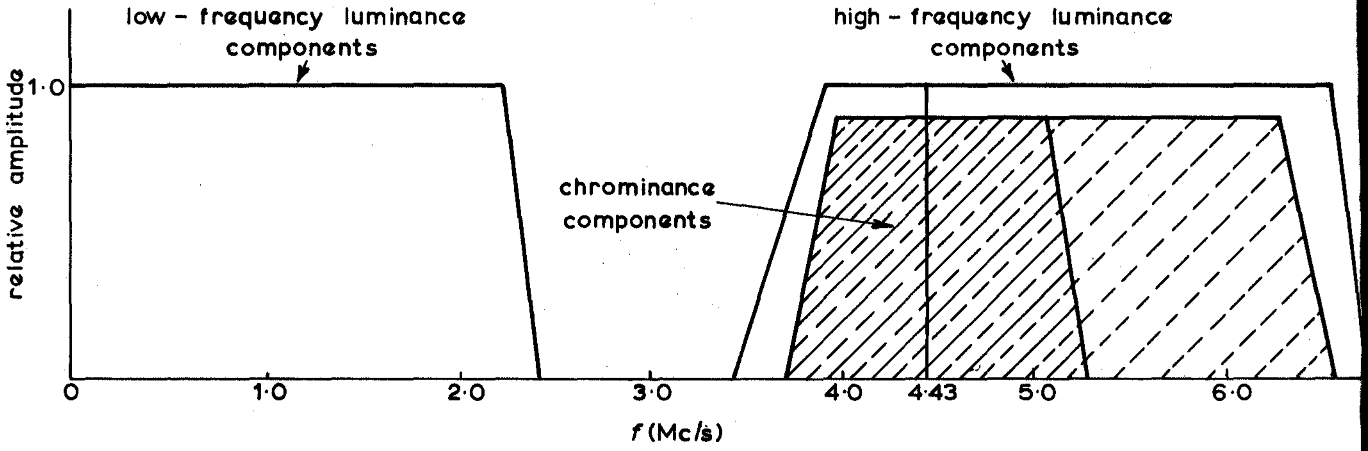


(b) Spectrum of output signal in which the high-frequency band has been obtained from the modifier.

Fig 3. Transcoding an "equi-band" colour signal


low - frequency luminance components
high - frequency luminance components
chrominance components
relative amplitude
1·0
0
1·0
2·0
3·0
4·0
4·43
5·0
f (Mc/s)

(a) Input signal spectrum after splitting into low and high-frequency bands.



(b) Spectrum of output signal in which the high - frequency band has been obtained from the modifier.

Fig 4. Transcoding a "wide - band I" signal